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APPLICATION NOTE 3202

# 5V Auxiliary Power Supply Teams LDO and Charge Pump

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*Abstract: To provide low-current 5V power in a 3.3V system, use a regulated-LDO chip to reduce 3.3V to 2.5V, then employ a charge-pump chip to double the 2.5V to 5V. To counteract the effect of high source impedance in the charge pump, provide feedback from the output to the LDO.*

The 5V auxiliary power supplied by "silver boxes" in most computer systems is being replaced by 3.3V auxiliary power, but some circuits still require a 5V supply. Such systems impose the messy task of creating a central 5V auxiliary supply from the 3.3V auxiliary supply, and then routing 5V power throughout the motherboard. If only a few ICs need 5V, there is an economical alternative: the use of inexpensive charge pumps as low-power 3.3V-to-5V converters, placed directly at the 5V loads.

Regulated charge pumps do this job nicely, but they are not common and they often command a premium price. You can build a regulated charge pump by combining an unregulated charge pump with a low-dropout regulator (LDO) that reduces the voltage to 5V. Unfortunately, that method requires an LDO rated for at least 7V, because an unregulated charge pump can deliver 7V when its 3.3V input goes to the upper limit of tolerance. That eliminates the possibility of using the latest low-cost LDOs, whose small geometry limits their maximum input to 6.5V.

You can reverse the order by placing the LDO in front of the charge pump, thereby reducing the 3.3V to 2.5V before doubling it. That approach allows the use of a low-cost, low-voltage LDO, but the charge-pump output impedance then becomes an issue. A low-cost charge pump (like the MAX1683) operating with low-valued (1µF) capacitors exhibits a typical output impedance of 35Ω, making it unusable at currents above a few milliamps.

The circuit of **Figure 1** shows a better way to cascade the charge pump with a voltage regulator. The LDO (IC1) reduces the 3.3V input to a lower value, and the unregulated charge pump (IC2) doubles that value to 5V. To cancel the voltage drop caused by charge-pump output impedance, the circuit feeds the 5V output back to the LDO, which alters its output as required to maintain output regulation. The available headroom (at least 1V) allows output currents to about 30mA, or (with larger capacitors) even higher.

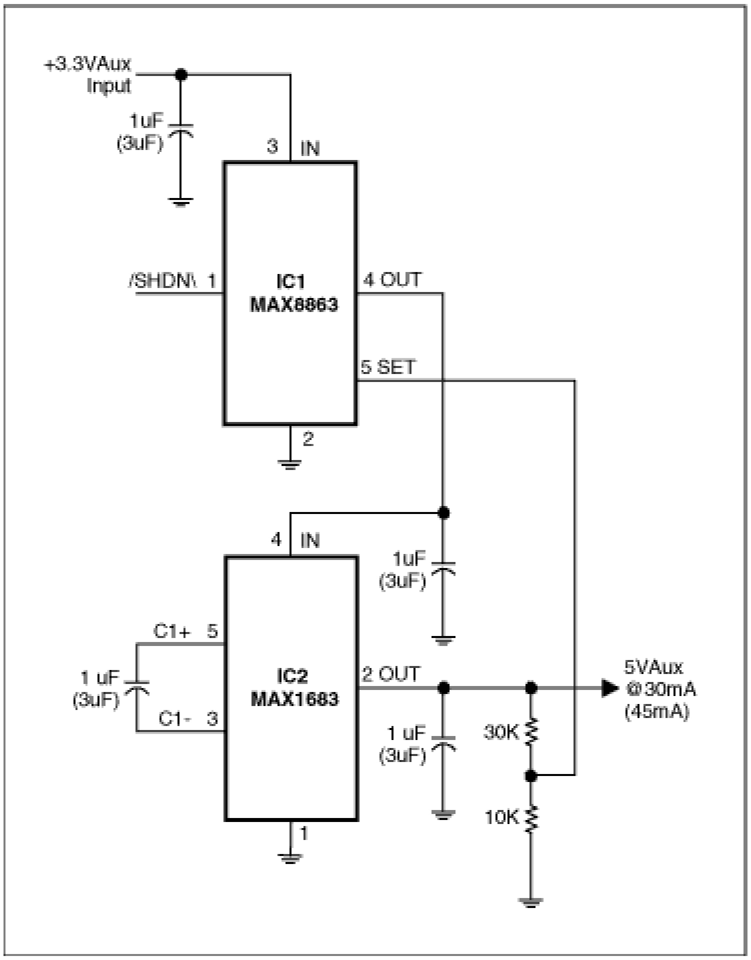


*Figure 1. This 5V supply, obtained by reducing the 3.3V input with an LDO (IC1) and doubling that output with a charge pump (IC2), minimizes the charge-pump output impedance by feeding 5V back to the LDO.*

Although it requires two ICs instead of a single regulated charge pump, this approach can be cheaper because unregulated charge pumps and low-current, low-voltage LDOs are used in higher volume. Furthermore, because the LDO and charge pump are available in SOT23 packages, the overall footprint of Figure 1 is competitive with that of a regulated-charge-pump circuit.

Table 1 demonstrates the circuit's ability to maintain output-voltage regulation while delivering up to 30mA, with the input, output, and flying capacitors all set to 1µF. Similarly, Table 2 shows the regulation for output currents to 45mA, with all capacitors set to 3µF.

**Table 1. All 1µF capacitors (input, output, and flying)**

| Vout (V) | Iout (mA) | Pout (mW) | Iin, Vin=3.3V (mA) | Pin (mW) | Efficiency (%) | Vout LDO (V) | Vripple (mVp-p) |
|---|---|---|---|---|---|---|---|
| 5.06 | 10 | 50.6 | 20.9 | 68.8 | 73.5 | 2.71 | 358 |
| 5.01 | 20 | 100.2 | 41.1 | 135.6 | 73.9 | 2.86/td> | 312 |
| 4.9 | 30 | 147 | 62.2 | 205.3 | 71.6 | 3.02 | 420 |

**Table 2. All 3µF capacitors (input, output, and flying)**

| Vout (V) | Iout (mA) | Pout (mW) | Iin, Vin=3.3V (mA) | Pin (mW) | Efficiency (%) | Vout LDO (V) | Vripple (mVp-p) |
|---|---|---|---|---|---|---|---|
| 4.99 | 10 | 49.9 | 20.37 | 68.8 | 74.2 | 2.63 | 154 |
| 4.99 | 20 | 99.8 | 40.4/td> | 133.3 | 74.9 | 2.76 | 104 |
| 4.98 | 30 | 149.4 | 60.6 | 200.0 | 74.7 | 2.89 | 154 |
| 4.93 | 40 | 197.2 | 80.5 | 265.7 | 74.2 | 3.02 | 192 |
| 4.9 | 45 | 220.5 | 90.5 | 298.7 | 73.8 | 3.09 | 214 |

As you can see, load current does not affect efficiency (which is approximately equal to the output voltage divided by twice the input voltage). Capacitor values affect the ripple voltage and available output current, but have little effect on efficiency.

| Related Parts | | |
|---|---|---|
| MAX1683 | Switched-Capacitor Voltage Doublers | Free Samples |
| MAX8863 | Low-Dropout, 120mA Linear Regulators | Free Samples |

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